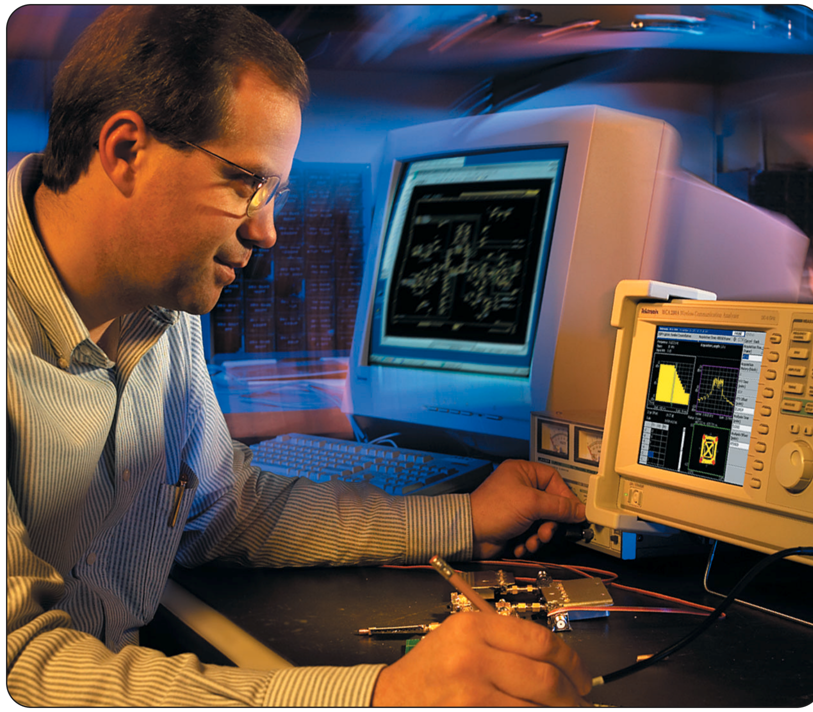
Multi-mode Analysis to Evaluate Designs for W-CDMA Compressed Mode Operations



COMPUTING COMMUNICATIONS VIDEO

Handovers – The Critical Function

One of the most critical operations in mobile radio systems is the handover – a function that requires careful and robust designs in user equipment (UE) and base station (BTS) transceivers. Both transceiver designers and network operators need to analyze transmissions and troubleshoot problems in these new systems. The Tektronix WCA200A Wireless Communication Analyzer promises the features needed to evaluate W-CDMA handover performance and track down the source of errors.

Introduction

W-CDMA systems manage handovers by briefly switching transmissions into a compressed mode – a method of inserting gaps in the signal to allow time for measurement and reporting functions. Compressed mode signals and their impact on the rest of a transmission cannot be evaluated with conventional swept spectrum analyzers. Transceiver designers and network operators need a new set of tools to analyze transmissions and troubleshoot problems in these new systems.

This application note describes the compressed mode operations that are used to manage handovers in a W-CDMA/UMTS radio environment and illustrates how synchronous multi-domain analysis of the resulting signals provides insight into transceiver designs. It demonstrates how the Tektronix WCA200A Wireless Communication Analyzer is used to capture uplink and downlink signals during long periods and provide correlated results in multiple domains – a comprehensive approach to evaluating W-CDMA handover performance and tracking down the source of errors.

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Handovers in Mobile Systems

The handover function is critical to maximizing the operating area while maintaining quality of service (QoS) in mobile systems. The handover is the process by which the radio access network changes the radio transmitters, radio access modes, or radio systems that are used to provide the bearer services to the UE, while maintaining a defined QoS.

Poorly executed handovers can disrupt calls, degrade QoS, and reduce the operating ranges of base stations. The ability for a UE to be handed over reliably between W-CDMA systems and GSM or TDD systems is particularly important as the newer networks are phased into existing infrastructures – they allow calls to continue without interruption and maximize resources through capacity sharing.

In W-CDMA systems, handovers are complex asynchronous events that make the evaluation of transceiver designs and network performance a challenging task. Errors that occur during handovers are unpredictable and must be captured seamlessly for several super frames in order to analyze their characteristics and trace their sources. In-depth analysis of compressed-mode signals and error conditions calls for correlated measurements in the frequency, time, modulation, and code domains.

Handovers from one base station to another are required in several situations. The most common situation is when the UE moves from one base station coverage area to another. The UE may move between base stations within the same radio system or into another system. The W-CDMA standard supports handovers to any GSM or TDD-CDMA network frequency bands that meet the specifications.

The multi-standard UE may change its frequency or radio access mode during a handover to a different base station. The UE may need a handover if its requested service level exceeds the current base station capacity. If a target base station cannot support the combination of bearer services (voice, data, multimedia, etc) that are provided by the current serving base station, some, or all of the bearer services may be handed over to another base station.

For multicall or conferencing connections, if the target system is a W-CDMA network and the target base station is not able to accommodate all calls in a multi-call mode, the calls that are handed over are selected according to operator preferences. The handover event can trigger changes to individual calls in any multi-call situation. If the target system is a GSM network, the call that is handed over is selected in the following order:[1]

1. The teleservice emergency call
2. Teleservice telephony
3. Calls of any other type according to operator preferences

Calls that cannot be handed over will be released.

How Handovers are Executed in W-CDMA Systems

Unlike previous GPS-synchronized systems, W-CDMA radio systems use asynchronous methods for base station site acquisition and handovers between base station resources. Within the W-CDMA system, handovers are “soft” (Intra-frequency Handovers) in order to minimize the interference on neighboring base stations and to allow the use of identical carrier frequencies. In a soft handover, the UE transmits and receives the same signal from both base stations simultaneously to make the transition as seamless as possible. Handovers are more complex when a multi-standard UE moves between base stations with different carrier frequencies or to a different network, such as GSM. These are known as “Inter-frequency Handovers". Both types of handover are handled with an assist from the UE mobile unit.

The multi-standard UE continuously monitors base stations with other frequencies and radio access systems that it supports. When the network senses the need for a handover, the BTS measures some system parameters and commands the UE to measure other parameters and report the results. Key parameters include carrier frequency, system type, traffic volume, and QoS levels.

Compressed Mode

When a handover is needed between systems, the BTS directs the UE to operate in compressed mode – a method of turning off transmissions for a portion of the 10 millisecond frame to create gaps that allow time for the UE to make measurements. Compressed mode operation can be achieved by decreasing the spreading factor, removing bits from the data (puncturing), or using higher level scheduling to allocate fewer timeslots for user traffic.

In compressed frames, the Transmission Gap Length (defined as slots N_{first} to N_{last}) is not used for data transmission. The instantaneous transmit power is increased in the compressed frame to maintain quality (BER, FER, etc.) during the periods of reduced processing gain. See Figure 1. The value of the power increment depends on the transmission time reduction method.

The higher protocol layer decides the number of frames to be used in the compressed mode. Compressed frames can be set to occur periodically, as shown in Figure 2, or on demand. The rate and type of compressed frames is variable and depends on the environment and the measurement requirements.

Separate compressed mode signals must be defined for uplink and downlink paths as well as for each mode, radio access technology, and frequency band supported by the UE. In typical applications, uplink data rates are doubled in compressed mode (using one half of the frame), while downlink data rates are set to double, or more, by higher protocol layers. Figure 2 shows examples of a compressed mode frame structure for uplink operations.

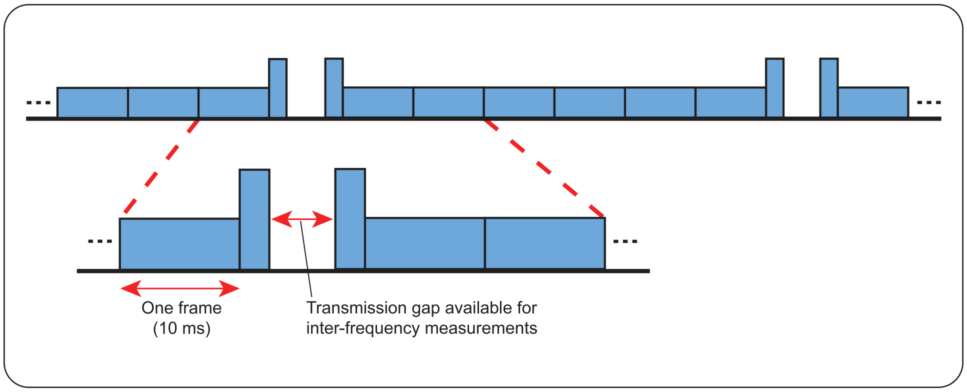


Figure 1. *Example of compressed mode transmission (3GPP TS25.212 V3.11.0).*[2]

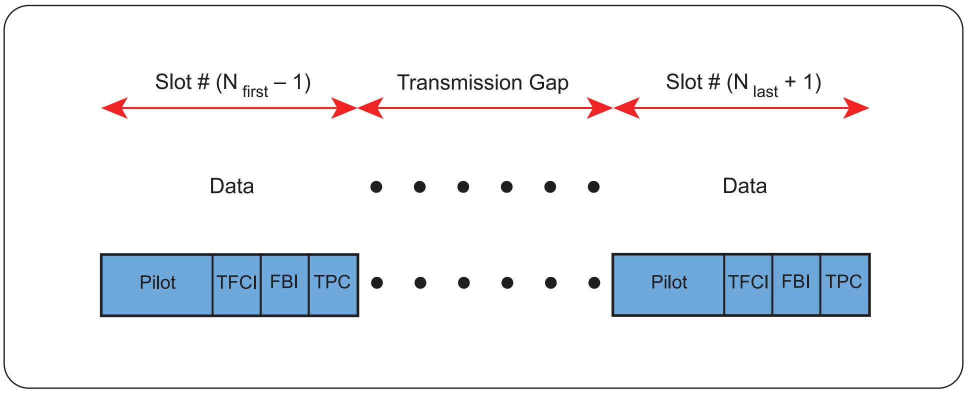


Figure 2. *Example of a compressed-mode frame structure for an uplink (3GPP TS25.212 V3.10.0).*[2]

Figure 3 illustrates two types of downlink frame structures that differ in the location of the TPC bits. Type A should be used to provide the maximum transmission gap for measurements; Type B is used to optimize power.

Creating the Transmission Gap Pattern Sequence

The UE and BTS perform a prescribed set of measurements within the *Transmission Gap Pattern Sequence* that is created in compressed mode. The Transmission Gap Pattern Sequence is requested by higher layer BTS protocols and the parameters are passed along to the UE by the BTS. The UE conducts only one set of measurements for each transmission gap pattern sequence.

Figure 4 illustrates a compressed mode sequence of alternating transmission gap patterns. Table 1 contains a complete list of the parameters that are used to define the sequence.

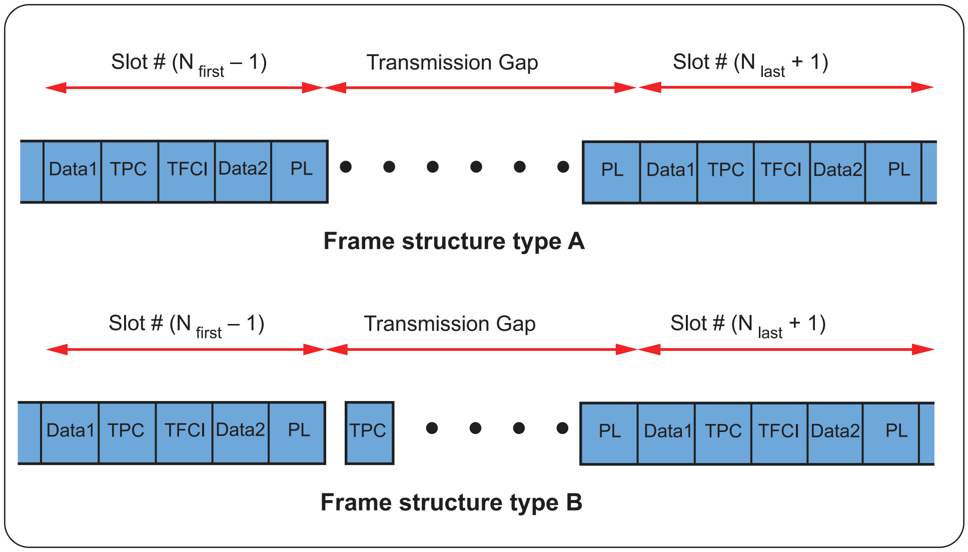


Figure 3. *Two examples of compressed mode frame structures for downlink (3GPP TS25.212 V3.10.0).*[2]

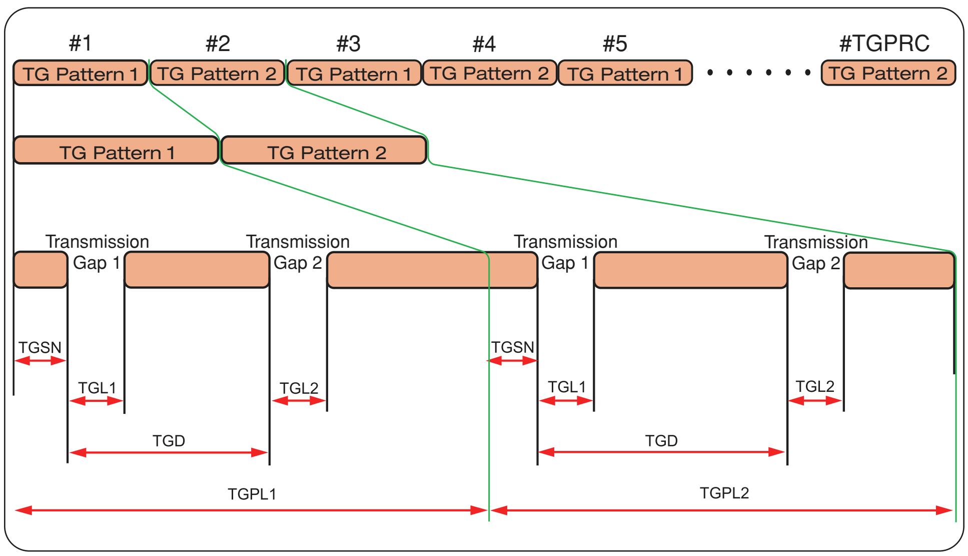


Figure 4. *Example of a compressed mode transmission gap pattern (3GPP TS25.215 V3.11.0).*[3]

Measurements made by UE and BTS during Compressed Mode

The UE and BTS measure the Layer 1 protocol to determine and report the status of Intra-Frequency, Inter-Frequency, Inter-System handovers, traffic volume, and quality of service levels.

First, the BTS transmits a “measurement control message” to the UE including the measurement ID and type of measurement to initiate. When the reporting is complete, the UE sends a “measurement reporting message” to the BTS with the measurement ID and the results. The measurement control message is broadcast in idle mode within the System Information. When the UE monitors base stations at other frequencies, modes, and radio access technologies, the BTS must direct the specific measurement needed to fulfill the requested handover. In W-CDMA, the Layer 1 measurements are reported to higher layers of protocol. In GSM, the measurements are reported only to the GSM terminal.

Table 1. Parameters of Transmission Gap Pattern Sequences

Note: TG pattern begins in a radio frame and the radio frame contains at least one TG pattern.

Parameter Name		Description
TGSN	(Transmission Gap Starting Slot Number)	Slot number of the first transmission gap slot in first radio frame of TG pattern
TGL1	(Transmission Gap Length 1)	Duration of the first transmission gap in the TG pattern, expressed in number of slots
TGL2	(Transmission Gap Length 2)	Duration of the second transmission gap in the TG pattern, expressed in number of slots. If this parameter is not set, TGL1 = TGL2
TGD	(Transmission Gap start Distance)	Duration between starting slot of first transmission gap and starting slot of second transmission gap
TGPL1	(Transmission Gap Pattern Length 1)	Duration of TG pattern 1, expressed in number of frames
TGPL1	(Transmission Gap Pattern Length 1)	Duration of TG pattern 2, expressed in number of frames
TGPRC	(Transmission Gap Pattern Repetition Count)	Number of TG patterns in the TG pattern sequence
TGCFN	(Transmission Gap Connection Frame Number)	Connection Frame Number of the first radio frame of the first pattern 1 in the TG pattern sequence

Table 2 lists the measurements made by the UE and the BTS during compressed mode.

Table 2: UE and BTS Measurements during Compressed Mode

	UE Layer 1 Measurements
CPICH RSCP	(Common Pilot Channel Received Signal Code Power)
PCCPCH RSCP for TDD	(Primary Common Control Physical Channel)
UTRA carrier RSSI	(UMTS Terrestrial Radio Access Received Signal Strength Indicator)
GSM carrier RSSI	(GSM Received Signal Strength Indicator)
CPICH Ec/No	(Received energy per chip divided by the power density in the band)
Transport Channel BLER	(BLock Error Rate)
UE Transmitted Power	
UE Rx-Tx Time Difference	
UE GPS Timing of Cell Frame for UE Positioning	

BTS Layer 1 Measurements
Received total wideband power
SIR/SIR_{error} (Signal to Interference Ratio)
Transmitted carrier power
Transmitted code power
Transport channel BER (Bit Error Rate)
PRACH/PCPCH Propagation
Acknowledged PRACH preambles
Detected PCPCH access preamble

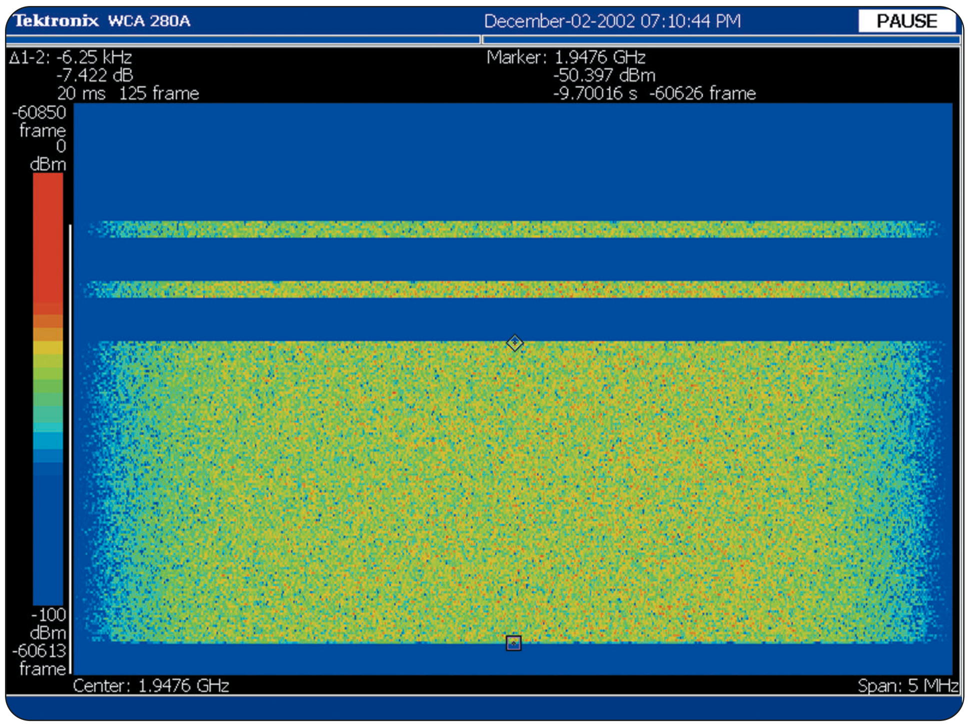
WCA200A Solution – Capturing Error Conditions and Analyzing Their Causes

Error conditions that arise during compressed-mode handovers can be brief and unpredictable. To be certain of catching these intermittent problems, power levels, frequency, and modulation information must be monitored before, during, and after they occur. Data must be captured seamlessly in order to preserve the signal characteristics and reveal the error sources. In-depth analysis of error conditions often requires the correlation of signal states in the frequency, time, modulation, and code domains.

The Tektronix WCA200A Wireless Communication Analyzer applies refined digital signal processing technology to the capture and analysis of radio signals. It is able to acquire long seamless records of complex signals and process them internally to display analysis results without the need for external computers. Amplitude versus time information is recorded continuously, revealing even brief, intermittent changes and the time they occurred within the long records. Internal DSP circuitry rapidly derives the frequency, modulation, and code characteristics from the stored data. Spectrogram and codogram displays add the third dimension of time to the spectrum and code versus power results. Time information is useful for identifying changes in behavior in each of the frequency and code domains during the measurement period, and linked cursors correlate the events for analysis in simultaneous displays of multiple domains.

A WCA200A with appropriate memory and software options can be used to perform verification tests or monitor system performance during handovers. The WCA200A can seamlessly acquire a full 10 seconds of signal during a handover and analyze the results in multiple display formats.

A spectrogram display of frequency versus time with color indicating the power density shows how well the UE performed at different frequencies during simulated handovers, as shown in Figure 5.



► ***Figure 5.*** *A Spectrogram; vertical axis is Time, horizontal axis is Frequency, and Power Density is represented by color.*

The Codogram display, shown in Figure 6, is another 3D display – the X-axis is OVSF (Orthogonal Variable Spreading Factor) or Channelization code (for UE) and the Y-axis is the time slot; power density for each code is represented by color.

The WCA200A is able to present up to three different displays simultaneously and link them with common cursors – clearly relating events to characteristics in all measurement domains. See Figure 7.

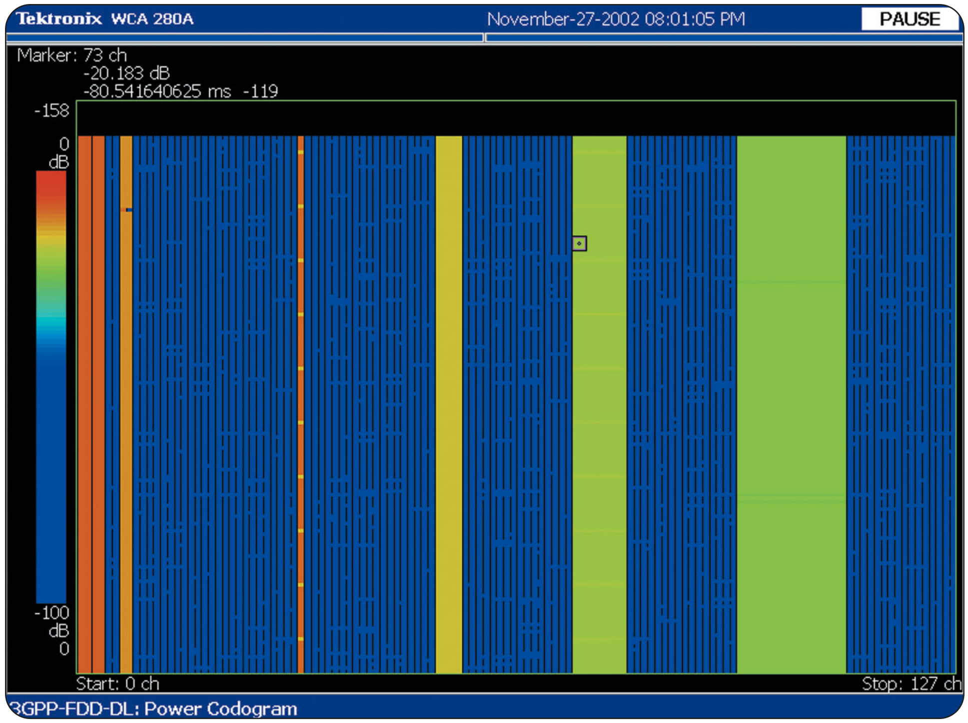


Figure 6. Codogram of W-CDMA downlink signal. Codogram vertical axis is Time Slot, horizontal axis is color.

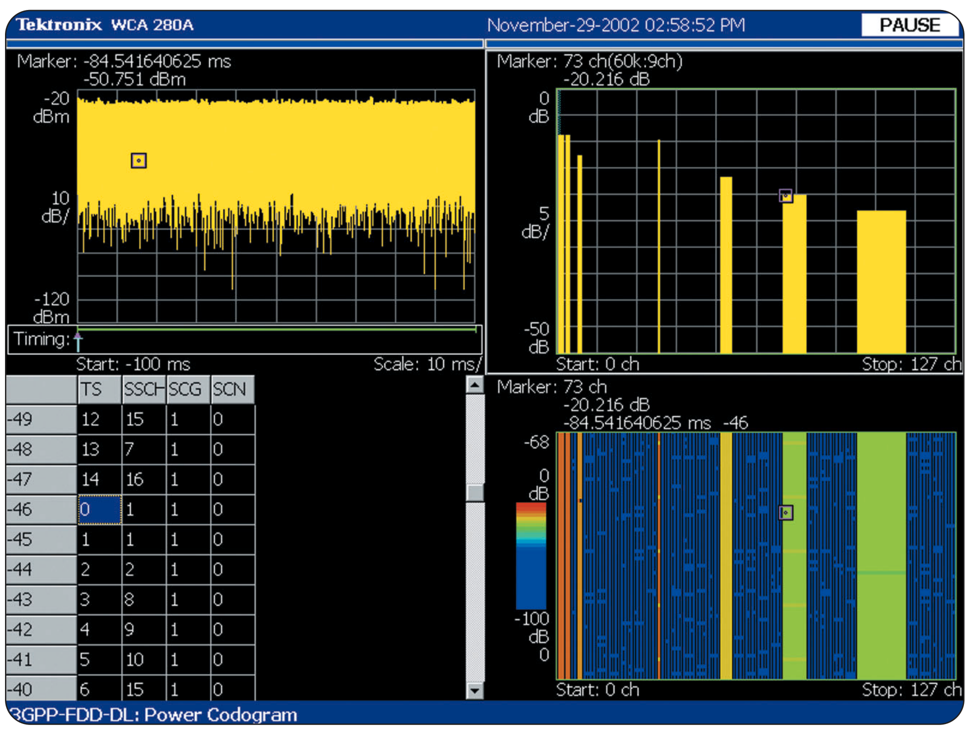
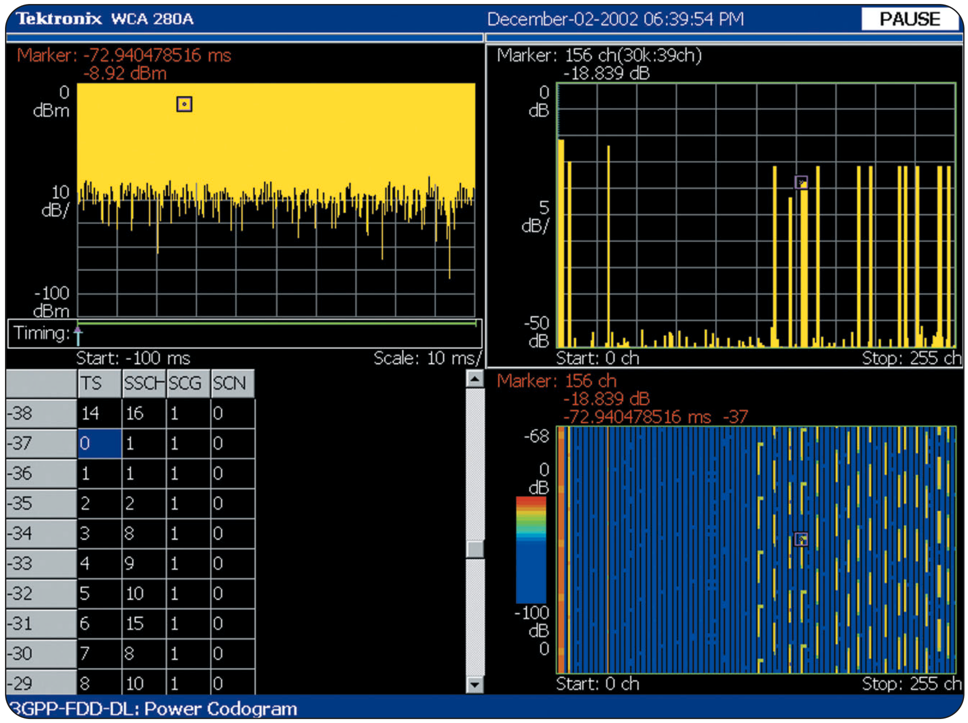


Figure 7. Linked cursors in three displays: Time vs. Power (upper left), Code Domain Power (upper right) and Codogram (lower right). Cursors are set to highlight a common time slot and code channel.

Analyzing Compressed Mode Signals

The WCA200A provides a unique and powerful tool for analyzing the compressed mode signals themselves in UE and BTS transceivers. Figure 8 shows a composite display of a compressed mode downlink signal with Time versus Power, Code Domain, and the Codogram linked by common cursors. The Codogram display clearly shows the gap period and timing of the compressed-mode signal and the increased thickness of the bars indicates that the data rate is higher than in the normal mode.



▶ ***Figure 8.*** *Composite display of a compressed mode downlink signal.*

Conclusion

W-CDMA compressed-mode handovers are complex intermittent operations – a real challenge to monitor and evaluate. The WCA200A Series uses specialized digital signal processing to capture uplink and downlink signals in long seamless records and analyze the results with powerful 3D displays. Results are correlated in the frequency, time, modulation, and code domains to provide clear insight into the system quality and/or potential sources of errors in radio networks and UE and BTS transceivers during handovers.

The WCA200A offers a new and comprehensive set of measurement tools to the designers of UE and BTS transceivers as well as the engineers and technicians who install and maintain radio networks in today's rapidly evolving mobile telecommunications environment.

References: Standards documents from the Third Generation Partnership Project (3GPP)

1. TS22.129 V3.6.0 “Handover Requirements between UMTS and GSM or other Radio Systems”
2. TS25.212 V3.11.0 Technical Specification Group Radio Access Network; Multiplexing and channel coding (FDD) (Release 1999)
3. TS25.215 V3.10.0 Technical Specification Group Radio Access Network; Physical layer – Measurements (FDD) (Release 1999)

Abbreviations

BER	Bit Error Rate
BLER	Block Error Rate
BTS	Base Transceiver Station
CCPCH	Common Control Physical Channel
CCTrCH	Coded Composite Transport Channel
CFN	Connection Frame Number
CPICH	Common Pilot Channel
DL	Downlink (Forward link)
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DSCH	Downlink Shared Channel
Ec/No	Received energy per chip divided by the power density in the band
FDD	Frequency Division Duplex
FER	Frame Error Rate
ISCP	Interference Signal Code Power
OVSF	Orthogonal Variable Spreading Factor (codes)
PCCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
PRACH	Physical Random Access Channel
RACH	Random Access Channel
RSCP	Received Signal Code Power
RSSI	Received Signal Strength Indicator
RX	Receive
SCH	Synchronization Channel
SF	Spreading Factor
SFN	System Frame Number
SIR	Signal-to-Interference Ratio
SNR	Signal-to-Noise Ratio
TF	Transport Format
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TPC	Transmit Power Control
TrCH	Transport Channel
TTI	Transmission Time Interval
TX	Transmit
UE	User Equipment
UL	Uplink (Reverse link)

WCA200A Series

The WCA200A Series are designed for designers and manufacturers of wireless components and devices, and are ideal for characterization, troubleshooting, and verification.

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